Small-scale Forest Economics, Management and Policy, 4(3): 359-376, 2005

Homestead Forest Resources and their Role in Household Economy: A Case Study in the Villages of Gazipur Sadar Upazila of Central Bangladesh

Md. Motiur Rahman[1], Yasushi Furukawa and Isao Kawata
Forest Management Laboratory, Faculty of Agriculture, Kochi University
B 200, Monobe, Nankoku-shi, Kochi 8502, Japan

Mohammed Mahabubur Rahman
Dhaka Imperial College
28 Mirpur Road, Dhaka 1205, Bangladesh

Mahbubul Alam
Department of Forestry, Shahjalal University of Science and Technology
Sylhet 3114, Bangladesh

This study examines the species composition, diversity and economic importance of homestead forests in the household economy of central Bangladesh. The study documents 57 homestead forest species and their main usage in 90 households across three villages of Gazipur Sadar Upazila. Homestead forests in Bangladesh comprise a mixture of fruit, timber and bamboo species. While superficially homestead forestry appears unimportant in rural livelihoods, in reality the contribution is huge, both as a source of food security and for other necessary household materials. A clear understanding of the physical characteristics and economic role of homestead forests in rural livelihoods is vital for ensuring sustainable resource management. Income and production of homestead forestry on a per hectare basis are found to vary widely between landholding size classes. Significant relationships are identified between forest performance (production and income) and species richness and education level. Homestead forestry appears to be a potential subsistence income generating land-use practice in the study area. The economic scope of homestead forestry can be further enhanced provided the appropriate species composition of the forest is achieved and the education of forest owners is ensured through targeted management and policy interventions.

Keywords: Homestead forests, species diversity, landholding size class, forest production, forest income

[1] PhD student in the United Graduate School of Agricultural Sciences, Ehime University, Matsuyama, Japan.

INTRODUCTION

In the literature, various terminologies are used to define *homestead forests* depending on context, for example, *village forests* (Douglas 1981), *tropical mixed garden* (Price 1982) and *homegarden* (Hochegger 1998). The village forest of Bangladesh is described as a multi-storied vegetation of shrubs, bamboos, palms and trees surrounding homesteads that produce materials for a multitude of purposes, including fuel, shelter, structural materials, fruits and other foods, fodder, resins and medicines (Douglas 1981).

One of the salient features of homestead forests is that they tend to be small-scale enterprises aimed at subsistence production and income generation. An Indonesian study found that income from homestead forests ranges from 6.6% to 55.7% of total income of homesteads, with an average of 21.1%, and depends on the size of the gardens, family needs and species composition (Soemarwoto 1987). Personal preferences and attitudes, socio-economic status and culture often reflect the appearance, structure and function of the homegardens (Christanty 1985). Abedin *et al.* (1988) reported that homestead forest owners in Bangladesh prefer fruit trees because these produce both fruit and fuel. However, Alam (1997) reported that homestead flora in Bangladesh comprised 182 tree species belonging to 48 families, and about 40 were fruit trees.

Planting trees around homesteads is an age-old practice in Bangladesh (Alam 1997). The area of homestead forest nationally is about 0.27 M ha, representing 10.5% of forestlands (GOB 1993). These forests supply 70% of timber and 90% of fuelwood and bamboo (Singh 2000). They are a major source of forest products, and play an important role in the economic life of the country by supplying the bulk of wood and other forest products in the market (Douglas 1981, GOB 1998). Although no recent estimates for growing stock of forests are available, estimates in 1980 indicated that growing stock per hectare for homestead forest was far higher (204 m^3/ha) than that of the government forest (31 m^3/ha) (GOB 1992).

Despite their importance, homestead forests are often overlooked by scientists and development agents as an important part of traditional farming systems largely because of their small size and apparent insignificance (Bunderson *et al.* 1990). In Bangladesh, there is no program specifically targeted to improve the overall productivity of homestead forests, nor to introduce yield-increasing technology (GOB 1993). Decision-makers have considered homestead forestry as a low-priority activity. For example, the first forest policy of British India, adopted in 1894, did not mention homestead forest management. A similar attitude of indifference was observed in the subsequent forest policies of 1955 and 1962 during the Pakistan regime and in the first national forest policy of Bangladesh, enacted in 1979. However, the latest national forest policy adopted in 1994 emphasised the encouragement of homestead forestry through provision of technical assistance, and pledged to promote development of labour-intensive forest-based cottage industries in rural areas (GOB 1995).

Homestead forests have also failed to gain the attention deserved in terms of research and extension support, credit facilities and utilisation and marketing facilities (GOB 1993). Salam *et al.* (2000) studied farmers' views of tree planting and found the decision to plant trees was governed mainly by economic rather than ecological concerns. Some attempts have been made to analyse the floristic and

quantitative stand structure of homestead forests (e.g. Millat-e-Mustafa *et al*. 1996, Motiur *et al*. 2005). Both studies found rich species diversity, and noted the relative dominance of fruit species over timber species. The latter study concluded that homestead stand structure could be manipulated effectively to optimise economic benefit without compromising species diversity. However, for policy formulation and to ensure sustainable development of homestead forests, a clear understanding of ecological functions, economic roles and factors affecting homestead forest production is essential, but remains lacking.

The objectives of the study reported here have been to document homestead-grown woody species and their usage, assess homestead forest species diversity, examine the role of homestead forest in household economy, and explore the relationship of species richness, education level and household size as causal factors for homestead forest production and income.

THE STUDY AREA

The study area consists of the three villages of Baghalbari, Mainpur and Painshail, under two unions – Kayaltia and Mirzapur of Gazipur sadar upazila (subdistrict) – which are located between $23^{\circ}53'$ and $24^{\circ}11'$ north latitude and $90^{\circ}20'$ and $92^{\circ}30'$ east longitude (BBS 1993) (Figure 1). Agroecologically, the area belongs to the Madhupur Tract. The soils developed over the Madhupur clay are deep red brown terrace, shallow red brown terrace and acid basin clays (BBS 2000). The area has a moderately equitable subtropical monsoon climate, with average maximum and minimum temperatures in the hottest and coolest months of 35°C and 12°C, respectively (BBS 2001). The rainy season runs from May to September, and the annual rainfall averages 2085 mm at the sub-district headquarter (BBS 2001).

The total number of households in the study villages as of 2004 was 1384,[2] and the total population 6,098 (BBS 1993). The unemployment rate for the population of age 10 years and above is just over 21%. About 31.9% of working people are engaged in the household economy and the remainder in agriculture, business, industry and other sectors (BBS 1993). The nearest urban settlement is Gazipur, which is about 40 km from Dhaka, the capital city of Bangladesh.

Agriculture is the main economic activity followed by business and services (BBS 2001). The main agricultural crops are HYV (high yield variety) paddy, wheat, jute, pulses, vegetables and oilseeds. A wide variety of trees, shrubs and thickets of bamboos form the groves that surround the village homesteads (BBS 2001). The nearby natural forest vegetation is classified as tropical moist deciduous forests that is mostly known as plainland sal *(Shorea robusta*) forest (Champion *et al.* 1965). Non-farm activities include manufacturing, wholesale and retail trade, restaurants and hotel services, and other community and social services (BBS 2001).

---

[2] This estimate has been obtained from records kept in holding tax registers of respective union offices in 2003-04. Although a population census was carried out in 2001, the results were not available at time of publication.

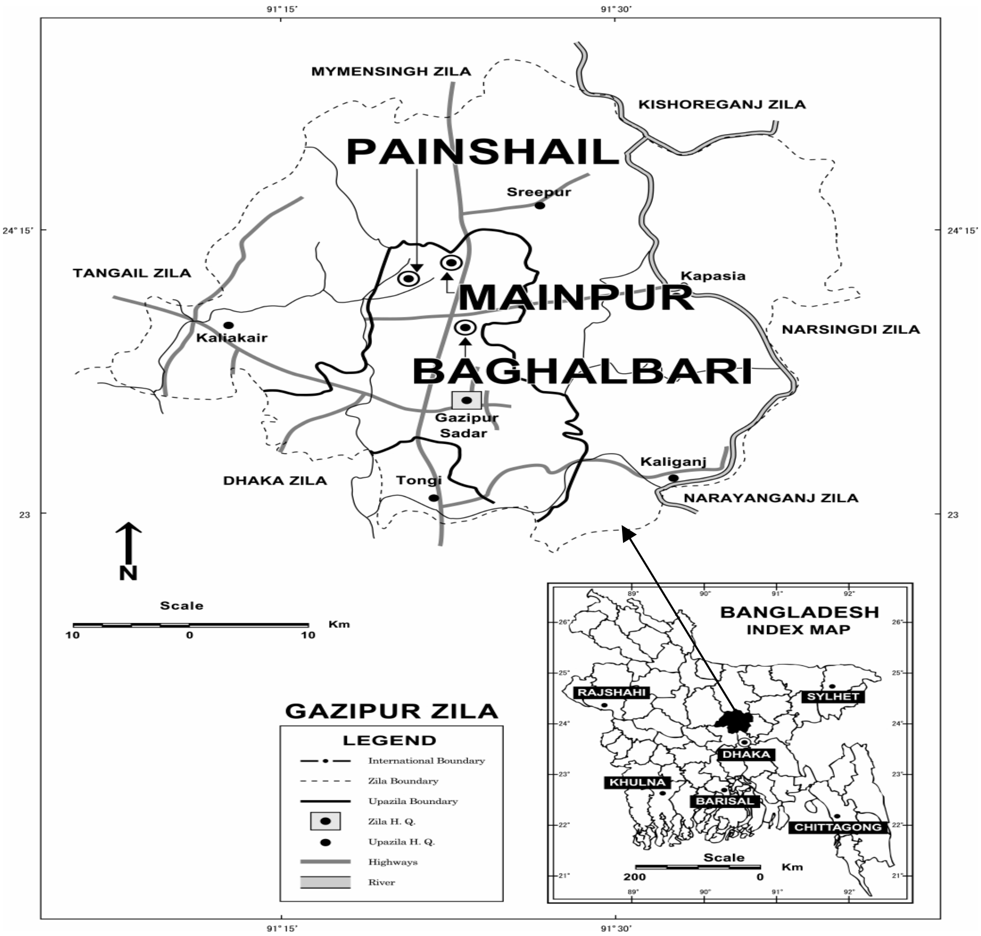

Figure 1. Location of study villages in Bangladesh

RESEARCH METHOD

BBS (2001) provided a broad classification of farm holdings for agricultural census purposes, in which the minimum size for a farming holding is set as 0.02 ha. Households possessing smaller areas are considered as non-farm households, suitable only for home gardens. Farming households are classified as small (0.02-1.01 ha), medium (1.02-3.03 ha) and large (>3.03 ha). Small farms are further divided into four classes, medium farms into two classes and large farms into four classes. Reviewing the information published in BBS (2001), the small farm class was grouped into two classes for this study. The lower two subclasses of the small class, including the non-farm households[3], were integrated as the marginal landholding class, while the upper two subclasses were integrated as the small landholding class. The BBS (2001) classification was followed for medium and

[3] Non-farm households were also considered in this study because they possess potential homestead forests.

large farm holding classes. Thus, the households were classified according to landholding size, as marginal (<0.4 ha), small (0.41-1.01 ha), medium (1.02-3.03 ha) and large (>3.03 ha).

This study is one of the three case studies undertaken by the authors in three different agroecological zones of Bangladesh. Gazipur subdistrict was purposively selected from central Bangladesh to represent the Madhupur Tract. Selection of the subdistrict was based on accessibility of the study area for data collection, proximity to suburban areas, temporal and financial constraints. A two-stage sampling approach was adopted. In the first stage three villages were randomly selected. Using the information from the holding tax registers from respective union council offices, and consulting senior citizens, schoolteachers and local village leaders, the households of the respective villages were divided into the selected landholding categories. Thirty households were selected at random from each village, giving proportionate weight to landholding size classes. In total, 39 households were selected from the marginal landholding class, 30 from the small landholding class, 15 from medium landholding class and six from the large landholding class, providing a sample size of 90 households, representing 6.5% of the total households of the villages.

Because little was known about the homestead forestry practices of the study area, exploratory information was collected, through three group discussions (one in each village) and 15 informal interviews with key informants, using a semi-structured questionnaire. The key informants included local government officials, senior citizens, schoolteachers, college students, village leaders, sawmill owners and furniture mart owners. With the feedback of the exploratory information, a detailed structured questionnaire was developed and household and homestead forest information was collected. Biophysical information obtained included species name, and number of stems of woody plants including bamboo (plants with girth at breast height (gbh) ≥10 cm). Socioeconomic information including amount of agricultural land, homestead land and homestead forestland, and family size, household income, homestead forest income, own consumption of homestead forest products, family occupation, and education of family members were collected through interviewing heads of households. The household survey was conducted from February through to August, 2004.

For diversity statistics, two non-parametric diversity indices, namely the Shannon-Wiener diversity index (H') and Pieluo's equitability index (J'), were derived. A one-way analysis of variance (ANOVA) was used to compare the means of various variables across the landholding size classes, after transforming the data using natural logarithm. Chi-squared tests of independence were used to detect relationships of species richness, education level and family size with homestead forest production and forest income. Dependency on forest income amongst farming and non-farming families was also tested using the χ^2 test of independence. Percentage data were transformed using arcsin, following Giovannetti *et al.* (2004).

RESULTS AND DISCUSSION

Characteristics of Sample Households

Farming – including crop production, poultry and horticulture – was the main occupation in the study area (49.9% of households), while 18.9% both farmed and owned a business, 10% had a main occupation of business, 11.1% had a main occupation of service and 11.1% had a main occupation as a day labourer. The average household size was 5.2 members. The average household size of marginal and small landholding classes was 4.9 members while that of medium and large classes were 5.5 and 8.7 members, respectively.

The average size of homestead forestland was 0.09 ha, which was 10.3% of the average total land possession. The average size of homestead forestland for the marginal landholding class was 0.05 ha while that of small, medium and large classes were 0.08 ha, 0.14 ha and 0.21 ha, respectively. It is notable that the size of homestead forestland increases with the increase of landholding size class, but the percentage of homestead forestland in relation to total land decreases because a higher proportion of the land is devoted to agricultural crops. The average number of years of schooling was 9.2. The amount of schooling increases with increase of landholding size classes, which might be related to family wealth. The average annual income of sample households was US$1180.80 (Table 1)[4]. It was observed that sawmilling and small-scale furniture making are the main enterprises that process and use the raw materials produced in homestead forests.

Table 1. Characteristics of the sample households

Land-holding size class	Total land (ha)	Agric. land (ha)	Other land[5] (ha)	Homestd land (ha)	Homestd forestland (ha)	Homestd forest land (%)	House-hold size (no.)	Educ. level (years)	Annual income (US$)
Marginal	0.21	0.12	0.01	0.08	0.05	25.7	4.9	7.5	822.9
Small	0.68	0.55	0.02	0.12	0.08	11.1	4.9	8.9	1061.5
Medium	1.45	1.21	0.04	0.19	0.14	9.6	5.5	12.3	1896.5
Large	4.00	3.66	0.06	0.28	0.21	5.3	8.7	14.3	2314.8
Overall	0.82	0.68	0.02	0.12	0.09	10.3	5.2	9.2	1180.8

Homestead Forest Species and their Usage

Table 2 reports the number and percentage distributions of various types of plants. Appendix A presents a complete list of woody species found in the sample households along with their main usage and average number of stems per household. From Appendix A, it can be seen that the study area has 57 species in total, including 25 fruit species, 25 timber species and 7 bamboo species. Jackfruit was the most abundant species, at 11.5 trees/household (12.3%), followed by giant bamboo 10.5 culms/household (11.3%) and mango 6.3 trees/household (6.8%). Fruit species were the highest in percentage terms (45.3%), followed by bamboo (29.5%) and timber species (25.2%). Apart from jackfruit and mango, coconut, guava, jujube,

---

[4] This is slightly lower than the national average household income of US$1299.60 (BBS 2004).

[5] Other land includes pond, graveyard and wasteland.

betel nut, blackberry and litchi were the main fruit trees, with mahogany, silk tree, teak, kadam (*Anthocephalus chinensis*) and acacia the main timber species. However, a large number of fruit and timber species occurred in relatively smaller numbers. A high percentage of fruit species may be linked with multipurpose usage of fruit trees as food, fodder, fuelwood and timber. For example, the main fruit species jackfruit and mango, which jointly represent about one fifth of the total stems (19.1%), contribute to the household by providing food, cash income, leaves as fodder and valuable timber. It was observed during an exploratory survey that next to teak, jackfruit was the most valuable timber in the local market.

Table 2. Stems of fruit, timber and bamboo species across landholding size classes[a]

	Landholding size class				
Type of plant	Marginal	Small	Medium	Large	Overall
Fruit	24.5 (49.2)	36.4 (48.3)	70.4 (40.9)	120.3 (44.0)	42.4 (45.3)
Timber	12.7 (25.6)	18.8 (25.0)	45.0 (26.1)	64.3 (23.5)	23.6 (25.2)
Bamboo	12.5 (25.1)	20.2 (26.8)	56.9 (33.0)	88.8 (32.5)	27.5 (29.5)
All	49.7 (100)	75.4 (100)	172.3 (100)	273.5 (100)	93.5 (100)

a. Figures in parentheses are percentages.

Out of 50 tree species identified in the area, 44 had timber use, including only 7 and 10 high and medium value timber species, respectively. The overall quality of fruit and timber species was relatively low due to constraints of germplasm available in the country. Farmers reported that in the past they were not concerned about the source of planting materials, and usually allowed wildings to grow. This practice could lead to selection of genetically inferior individuals with low yield. Although farmers grew some species in designated areas – for instance, bamboo in the northwest corner for shade management and protection from storms – they did not follow any definite spacing or planting design for species grown, due to lack of technical knowledge. Lack of specific planting design and standard spacing may affect growth, form and yield of the trees as well as tie-up space that could otherwise be used to grow more trees.

Homestead Forest Species Diversity and its Implications

Table 3 compares the average number of species per household and diversity indices. The average number of species per household was 18.9, the Shannon-Wiener diversity index (H') was 3.43, and Pieluo's equitability index[6] (J') was 0.85. The number of species per household and value of species diversity indices steadily increase with the increase of landholding size class. Diversity indices of timber and bamboo species have a greater increase than fruit species. Relatively low values of J' for fruit species for the two smaller landholding classes indicate concentration on a

[6] The equation for the Shannon-Wiener index, from Odum (1971), is $H' = -\Sigma[p_i Ln(p_i)]$, and the equation for the Equitability index, from Pielou (1966), is $J' = H'/H'_{max}$. Here p_i is the proportion of the number of i^{th} species (n_i) to the total number of individuals (N), i.e. $p_i = n_i/N$ and $H'_{max} = Ln(S)$, where S is the total number of species found in all the samples.

few fruit species, typically jackfruit and mango. On the other hand, both H' and J' for all plants for both medium and large landholding classes are higher than for the remaining two classes, which is related to the presence of greater numbers of species in these two classes.

Table 3. Average number of species, Shannon-Wiener Diversity Index (H') and Pieluo Equitability Index (J')

Landholding size class	Average number of species per household	$H'_{all\ plant}$	$J'_{all\ plant}$	H'_{fruit}	J'_{fruit}	H'_{timber}	J'_{timber}	H'_{bamboo}	J'_{bamboo}
Marginal	13.4	3.22	0.82	2.49	0.77	2.51	0.81	1.22	0.76
Small	18.1	3.37	0.84	2.55	0.79	2.61	0.82	1.61	0.90
Medium	27.7	3.43	0.85	2.64	0.97	2.7	0.84	1.71	0.88
Large	36.0	3.46	0.85	2.65	0.9	2.9	0.82	1.67	0.86
Overall	18.9	3.43	0.85	2.60	0.81	2.72	0.85	1.71	0.88

The overall species diversity ($H' = 3.43$) is higher in the study area than that of north-eastern Bangladesh, of $H' = 3.1$ (from Motiur *et al.* 2005) and adjacent deciduous sal forests of $H' = 2.81$ (from Motiur *et al.* 2004). The moderately high J' value of 0.85 indicates the richness of biodiversity and presence of symbiosis – i.e. mutualism, parasitism and commensalism (as defined by Odum 1971) amongst the various homestead species – and depicts a sustaining, stabilising and productive homestead forest community. Rich diversity of the homestead forests preserves wide genetic resources that may help to maximise the utilisation of homestead forest products.

Role of Homestead Forests in the Household Economy

The average annual value of gross production of homestead forest is US$228.2 per household, of which US$89.2 (39.1%) is used by the household and US$138.9 (60.9%) is sold. The overall contribution of homestead forest income to average household income is 11.8%. Large households received the highest forest income, US$397.1, whereas marginal households received the minimum forest income (US$67.3). The findings further indicate that homestead forest production, own consumption and income increase with increasing of landholding size class (Table 4).

Total forest gross production per household per year is US$228.2 (US$ 2670.9/ha), which is 1.2 times as high as that of a monoculture of jackfruit, 1.6 times that of a monoculture of mango, and 5.5 times that of HYV paddy cultivation[7]. These findings suggest that homestead forestry is a more profitable option than other land-use systems, and the diverse species composition of homestead forests leads to higher gross production on a per hectare basis than other monocultures. The fact that overall income from homestead forests of US$138.9 is 11.8% of average annual household income, and households sold a higher proportion of the homestead forest products

[7] Gross production for the various crops is calculated from data published in BBS (2003).

(60.9%) than own consumption (39.1%), reveals the importance of homestead forestry as a supplementary cash income generating activity in the study area (Table 6).

Table 4. Average annual income, homestead forest income, forest production and forest own consumption across landholding size classes

Landholding size class	Annual household income (US$)	Homestead forest income (US$)	Income from other sources (US$)	Contribution of forest income to annual income (%)	Homestead forest production (US$)	Homestead forest own consumption (US$)
Marginal	822.9	67.3	755.6	8.2	119.9	52.6
Small	1061.5	122.4	939.1	11.5	212.0	89.6
Medium	1896.5	254.8	1641.6	13.4	396.9	142.1
Large	2314.8	397.1	1917.8	17.2	590.7	193.6
Overall	1180.8	138.9	1041.9	11.8	228.2	89.2

A χ^2 test of independence between family occupation and contribution of forest income to annual household income revealed that families with farming background depend more on forest income than others (Table 5).

Table 5. Dependency between family occupation and forest income

Income class	Occupational class[a]		
Arcsin (homestead forest income/total income)%[b]	Farming families[c]	Others[d]	Total
<12.92	10(15.2)	12 (6.8)	22
<5%	45.5%	54.5%	100%
12.92-22.79	31 (28.2)	10 (12.8)	41
5-15%	75.6%	24.4%	100%
>22.79	21 (18.6)	6 (8.4)	27
>15%	77.8%	22.2%	100%
Total	62	28	90
χ^2	7.50* (calculated)	5.99 (tabulated)	
df	2		

[a] Figures in parenthesis are expected frequencies under null hypothesis; * indicates significant at p=0.05.
[b] The arcsin transformation moves very low or high values towards the centre, which enables percentage data to be used in the χ^2 test of independence. Example can be found in Giovannetti *et al.* (2004).
[c] Farming families include both full-time farmers and farmers owning a business.
[d] The others class include businessmen, service holders and day labourers.

Fruit and timber contributed a major and equal share of homestead forest income, of US$59.8 (43.0%) and US$59.2 (42.6%) respectively, while bamboo and fuelwood

only contributed US$12.6 (9.0%) and US$7.3 (5.3%) respectively. However, 77.1% of fuelwood and 45.4% of bamboo were consumed for household purposes. Income from all types of forest products increases with an increase of household size, whereas the proportion of income from fruits tends to decrease as landholding size class increases. In general, the percentage of own use of fruit, fuelwood and bamboo decreases as landholding size class increases; however, use of timber did not follow any definite pattern (Tables 6 and 7). Overall, growers used 39.9% of the various forest products, which contributed food, fuel, timber and bamboo to the household economy. Further, the diverse forest products available round the year provide food security, which is consistent with the findings of Christanty *et al*. (1986) and Karyono (1990).

Table 6. Production, own consumption and income from homestead forest (in US$)

LHSC	HFP	TP	FP	FuP	BP	TotSU	TSU	FSU	FuSU	BSU	HFI	TI	FI	FuI	BI
Marginal	119.9	33.4	52.2	23.5	10.9	52.6	7.4	20.2	19.6	5.4	67.3	26.0	32.1	3.9	5.5
Small	212.0	82.4	80.8	29.2	19.6	89.6	29.6	27.2	22.8	10.0	122.4	52.8	53.6	6.4	9.6
Medium	396.9	162.8	143.3	48.5	42.4	142.1	49.8	38.9	35.7	17.7	254.8	113.0	104.3	12.8	24.7
Large	590.7	246.8	212.2	61.4	70.3	193.6	73.3	52.8	40.4	27.1	397.1	173.5	159.4	20.9	43.2
Over all	228.2	85.5	87.6	32.1	23.0	89.2	26.3	27.8	24.7	10.4	138.9	59.2	59.8	7.3	12.6

Key: LHSC=landholding size class, HFP = homestead forest production, TP = timber production, FP = fruit production, FuP = fuelwood production, BP = bamboo production, TotSU = total self-use, TSU = timber self-use, FSU = fruit self-use, FuSU = fuelwood self-use, BSU = bamboo self-use, HFI = homestead forest income, TI = Income from timber, FI = income from fruit, FuI = income from fuelwood, BI = income from bamboo.

Table 7. Percentage distribution of homestead product sale and own consumption

Land-holding size class	All products		Timber		Fruit		Fuelwood		Bamboo	
	Sale	Own consump-tion	Sale	Own consump-tion	Sale	Own consump-tion	Sale	Own consump-tion	Sale	Own consump-tion
Marginal	56.1	43.9	77.8	22.2	61.4	38.6	16.5	83.5	50.3	49.7
Small	57.7	42.3	64.1	35.9	66.4	33.6	22.0	78.0	48.9	51.1
Medium	64.2	35.8	69.4	30.6	72.8	27.2	26.4	73.6	58.3	41.7
Large	67.2	32.8	70.3	29.7	75.1	24.9	34.1	65.9	61.5	38.5
Overall	60.9	39.1	69.3	30.7	68.3	31.7	22.9	77.1	54.6	45.4

Table 8 reports the average number of person days required per year for the various homestead forestry activities according to gender and source of labour across landholding size classes. The number of person days required averages 46.1/household/year (538.3/ha/year), which can be considered relatively high considering the fact that homestead forestry involved only raw material production; no secondary or finished products are produced by growers in the study area. The growers' families provided 76% of the labour requirements. The percentage of hired labour increases with the increase of landholding size class. Female workers provide

almost half (49.3%) of the labour requirements. The results reveal that homestead forests contribute to the household economy by providing subsistence cash income, employment opportunities and various household materials.

Table 8. Employment generated in homestead forestry (number of person days/year)

Land-holding size class	Family, male	Family, female	Hired, male	Hired, female	Total	Family person day (%)	Hired person day (%)	Male person day (%)	Female person day (%)
Marginal	109.6 (36.2)	14.8 (55.7)	1.3 (4.9)	0.8 (3.2)	26.6 (100)	91.9	8.1	41.1	58.9
Small	16.7 (40.5)	17.9 (43.3)	4.6 (11.1)	2.1 (5.1)	41.2 (100)	83.8	16.2	51.6	48.4
Medium	24.9 (31.7)	27.2 (34.7)	17.4 (22.2)	8.9 (11.3)	78.3 (100)	66.5	33.5	54.0	46.0
Large	30.0 (25.8)	33.7 (28.9)	37.3 (32.0)	15.5 (13.3)	116.5 (100)	54.7	45.4	57.8	42.2
Overall	15.9 (34.5)	19.2 (41.6)	7.5 (16.2)	3.6 (7.8)	46.1(100)	76.0	24.0	50.7	49.3

Landholding Size Classes and Forest Characteristics

One-way analysis of variance (ANOVA) was used to test for differences in per hectare forest production, forest income and number of stems of fruit trees, timber trees, bamboo culms and all plants, across landholding size classes. Mean annual gross forest production per hectare differs significantly (at the 1% level) while mean annual forest income per hectare differs significantly (at 5% level) across landholding size classes. The mean number of stems of timber trees per hectare differs significantly (at 5% level) across landholding classes while the mean number of stems of bamboo culms per hectare differs significantly (at 1% level) across landholding classes. However, the mean number of stems of fruit trees per hectare did not differ significantly across landholding size classes. The mean number of all plants per hectare differs significantly (at 5% level) across landholding size classes (Tables 9 and 10).

The relatively higher return for larger landholding classes may be a combined effect of efficient land utilisation and greater species richness that allows product diversification and effective utilisation of land potential. Again, product diversification has marketing implications to maximise homestead forest income. Farmers reported short seasonality and volatile market prices as the two main causes of lower income from fruit sales. Households with a wide range of diversified products for marketing are less likely to be susceptible to seasonality of crop harvests and volatility of market prices. Most of the fruit crops (jackfruit, mango, litchi and blackberry) grown in the area are summer fruits, which are harvested during April to July (BBS 2000), so growers have a relatively short period for marketing fruit crops. Because households in the smaller landholdings concentrate mainly on jackfruit and mango, they might be more prone to market price volatility. Smaller landholdings also have a very limited amount of timber for sale, which detracts from homestead forest income.

Table 9. Mean production, income and number of stems of different plant categories across landholding size classes

Variable	Marginal		Small		Medium		Large	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean
Forest production	39	7.67	30	7.90	15	7.90	6	7.94
Forest income	39	6.11	30	7.01	15	7.35	6	7.55
Stems of fruit trees	39	6.17	30	6.11	15	6.18	6	6.41
Stems of timber trees	39	5.41	30	5.42	15	5.73	6	5.75
Stems of bamboo culms	39	3.23	30	4.64	15	5.92	6	5.95
Stems of all plants	39	6.89	30	6.88	15	7.05	6	7.17

Table 10. Results of ANOVA for forest production, forest income and number stems of different plant categories across landholding classes

Variable	F (calculated)	p-value
Forest production	4.911	0.003**
Forest income	2.728	0.048*
Stems of fruit trees	1.015	0.390
Stems of timber trees	2.777	0.046*
Stems of bamboo culms	5.712	0.001**
Stems of all plants	3.915	0.011*

* F value significant at 5%; ** F value significant at 1%.

Relationship between Household Characteristics and Forest Production and Income

Chi-squared tests of independence revealed significant relationships of species richness and education level to homestead forest production and forest income at the 0.5% level, while no significant relationship was observed for household size (Tables 11 and 12). These findings may imply that an increase in education level leads to improved management of homestead forests, causing an increase in forest production and forest income. Increases in species richness improve utilisation of site capability and contribute to product diversification, which increases forest production and income. Absence of any relationship of family size to forest production and forest income may imply that there is no scarcity of labour for homestead forestry activities in the study area.

Table 11. Relationship between household characteristics and forest production[a]

Forest production class	Species richness class (no. of species/household)				Education level class (years)				Household size class (members)		
(US$)	1-15	16-25	>25	Total	0-5	6-12	>12	Total	<5	≥5	Total
<100	25	2	0		17	7	2		11	15	
	(11.1)	(10.2)	(5.7)	27	(11.0)	(9.5)	(5.5)	26	(9.8)	(16.2)	26
	92.6%	7.4%	0.0%	100%	65.4%	26.9%	7.7%	100%	42.3%	57.7%	100%
101-250	10	20	3		17	10	6		12	21	
	(13.6)	(12.5)	(7.0)	33	(13.9)	(12.1)	(7.0)	33	(12.5)	(20.5)	33
	30.3%	60.6	9.1%	100%	51.5%	30.3%	18.2%	100%	36.4%	63.6%	100%
>250	2		16		4	16	11		11	20	
	(12.3)	12 (11.3)	(6.3)	30	(13.1)	(11.4)	(6.5)	31	(11.7)	(19.3)	31
	6.7%	40.4%	53.3%	100%	12.9%	51.6%	35.5%	100%	35.5%	64.5%	100%
Total	37	34	19	90	38	33	19	90	34	56	90
χ^2	60.9^{***} (cal.)		14.86 (tab.)		18.6^{***}(cal.)		14.86 (tab.)		0.32 (cal.)	5.99 (tab.)	
df		4				4				2	

[a] Figures in parenthesis are expected frequencies under the null hypothesis. *** significant at p = 0.005.

Table 12. Relationship between household characteristics and forest income[a]

Forest income class	Species richness class (no. of species/household)				Education level class (years)				Household size class (members)		
(US$)	1-15	16-25	>25	Total	0-5	6-12	>12	Total	<5	≥5	Total
<100	29	11	2		28	11	3		19	23	
	(17.3)	(15.9)	(8.9)	42	(17.7)	(15.4)	(8.9)	42	(15.9)	(26.1)	42
	69%	26.2%	4.8%	100%	66.7%	26.2%	7.1%	100%	45.2%	54.8%	100%
101-200	5	17	2		8	9	7		6	18	
	(9.9)	(9.1)	(5.1)	24	(10.1)	(8.8)	(5.1)	24	(9.1)	(14.9)	24
	20.8%	70.8	8.3%	100%	33.3%	37.5%	29.2	100%	25.0%	75.0%	100%
>200	3	6	15		2	13	19		9	15	
	(9.9)	(9.1)	(5.1)	24	(10.1)	(8.8)	(5.1)	24	(9.1)	(14.9)	24
	12.5%	25.0%	62.5%	100%	8.3%	54.2%	37.5%	100%	37.5%	62.5%	100%
Total	37	34	19	90	38	33	19	90	34	56	90
χ^2	51.27^{***} (cal.)		14.86 (tab.)		23.86^{***}(cal.)		14.86 (tab.)		2.66 (cal.)		5.99 (tab.)
df		4				4				2	

[a] Figures in parenthesis are expected frequencies under the null hypothesis; *** significant at p = 0.005.

CONCLUDING COMMENTS

Homestead forests in the Gazipur Zila of Bangladesh are species rich and support a mixture of fruit, timber and bamboo species with a variety of usage. High species diversity renders homestead forests ecologically stable and sustainable. Gross production from these forests is high, contributing 11.8% of household income on average. The study suggests that homestead forestry can be utilised effectively as a

subsistence income-generating and employment-creating production system. However, statistical tests indicate that both gross annual forest production and income differ across landholding size classes. Further, species richness and education level have clear linkages with forest production and forest income. Some policy and management interventions are required to utilise effectively the real potential of homestead forestry to maximise benefits. To enhance forest production and income, it is imperative that forest policy encourage homestead owners, especially those with marginal and small landholdings who represent the vast majority of forest owners, to diversify their crops by selecting a judicious mixture of fruit, timber and bamboo species. For selection of appropriate mixtures, species optimisation-modelling research may be encouraged and economic potential of rare species may be explored. More land can be put under homestead forest production; attention may be given to nearby wastelands and uplands that usually surround homesteads. Extension education programs are imperative, especially targeting farming families who depend most on forest income and usually lack educational opportunities. As it is evident that the study area has high unemployment, establishment of small-scale forest-based industries (for instance, canned fruit products and wood and bamboo-based cottage industries) may also be explored as employment and income-generating household activities.

ACKNOWLEDGMENTS

The authors wish to thank the homestead forest owners, local senior citizens, schoolteachers and many other people who have kindly donated their valuable time and provided information for the research. Special thanks are due to Steve Harrison, School of Economics, The University of Queensland, and Jiro Tsukamoto, Education and Research Centre for Subtropical Field Science, Kochi University, for their kind advice on how to put this paper together. The authors also express their gratitude to the two anonymous reviewers for their critical comments and suggestions to improve the paper.

REFERENCES

Abedin, M.A., Lai, C.K. and Ali, M.O. (1988), *Homestead plantation and agroforestry in Bangladesh*, BARI/RWEDP/Winrocks, Dhaka.

Alam, M.K. (1997), 'Domestication and conservation potential of homestead forests in Bangladesh', in *Proceedings of XI World Forestry Congress, Antalya, Turkey*, Vol. 2, p. 203.

BBS (Bangladesh Bureau of Statistics) (1993), *Bangladesh Population Census 1991*, Zila: Gazipur, Government of Peoples Republic of Bangladesh (GOB), Dhaka.

BBS (Bangladesh Bureau of Statistics) (2000), *1998 Year Book of Agricultural Statistics*, GOB, Dhaka.

BBS (Bangladesh Bureau of Statistics) (2001), *Census of Agriculture, 1996*, Zila Series-Gazipur, GOB, Dhaka.

BBS (Bangladesh Bureau of Statistics) (2003), *Statistical Year Book 2001*, GOB, Dhaka.

Bhuyan, H.H. (2004), Director, Census, Bangladesh Bureau of Statistics, Dhaka, personal communication.

Bunderson, T.W., Wakeel, A.E.L., Saad, Z.A. and Hashim, I. (1990), 'Agroforestry practices and potential in Western Sudan', in W.W. Budd, I. Ducchart, L.H. Hardsesty and F. Steiner (eds), *Planning for Agroforestry*, Elsevier, Oxford, pp. 227-246.

Champion, H.G., Seth, S.K. and Khattak, G.M. (1965), *Forest Types of Pakistan*, Pakistan Forestry Institute, Peshawar.

Christanty, L. (1985), 'Homegardens in tropical Asia: a special reference to Indonesia', a paper presented at the First International Workshop on Tropical Homegardens, Institute of Ecology, Padjadjaran University, Bandung, Indonesia.

Christanty, L., Abdoellah, O.S, Marten, G.G. and Iskandar, J. (1986), 'Traditional agroforestry in West Java: the pekarangan (homegardens) and kebun-talun (annual-perennial rotation) cropping systems', in G.G. Marten (ed.), *Traditional Agriculture in Southeast Asia*, Boulder, Colorado, pp. 132-158.

Douglas, J.J. (1981), 'Supply and demand of forest products and future development strategies', Field Document No. 2, UNDP/FAO/Planning Commission (GOB Project BGD/78/010, FAO, Rome.

Giovannetti, M., Sbrana, C, Avio, L. and Strani, P. (2004), 'Patterns of below-ground plant interactions established by means of arbuscular mycorrhizal networks', *New Phytologist*, 164(1): 175-181.

GOB (Government of Peoples Republic of Bangladesh) (1992), *Forestry Master Plan (Forest Policy)*, Ministry of Environment and Forests, Dhaka.

GOB (1995), *Forest Policy of 1994*, Bangladesh Gazette, 6 July 1995, pp. 241-244, Dhaka.

GOB (1993), *Forestry Master Plan (Environment and Land use)*, Ministry of Environment and Forests, Dhaka.

GOB (1998), *The Fifth five Year Plan (1997-2002)*, Planning Commission, Ministry of Planning, Dhaka.

Hochegger, K. (1998), *Farming like the Forest: The Traditional Home Garden System in Srilanka*, Margraf, Weikersheim, Germany, pp. 203.

Karyono (1990), 'Home Gardens in Java: their structure and function', in K. Landauuer and M. Brazil (eds), *Tropical Home Gardens*, The United Nations University, Tokyo, pp. 138-146.

Motiur, M.R., Tsukamoto, J., Furukawa, Y., Kawata, I., Rahman, M.M. and Alam, M. (2004), Diversity of Forest Tree Species of Tropical Moist Deciduous Forest of Madhupur Tract of Central Bangladesh, unpublished report, Kochi University, Japan.

Motiur, M.R., Tsukamoto, J., Furukawa, Y., Shibayama, Z. and Kawata, I. (2005), 'Quantitative stand structure of woody components of homestead forests and its implications on silvicultural management, a case study in Sylhet Sadar Upazila, Bangladesh', *Journal of Forest Research*, 10(4): 285-294, The Japanese Forestry Society and Springer-Verlag, Tokyo.

Millat-e-Mustafa, M.D., Hall, J.B. and Tklehaimanot, Z. (1996), 'Structure and floristics of Bangladesh homegardens', *Agroforestry Systems*, 33(3): 263-280.

Odum, E.P. (1971), *Fundamentals of Ecology*, 3rd edn, Toppan Printing Company, Tokyo.

Pielou, E.C. (1966), 'The measurement of diversity in different types of biological collections', *Journal of Theoretical Biology*, 13:131-144.

Price, N. (1982), 'he tropical mixed garden: an agroforestry component of the small farm', in N. Price, (ed.), *Agroforestry for Humid Tropics*, p. 40, CATIE, Turrilba, Costa Rica.

Salam, M.A., Noguchi, T. and Koike, M. (2000), 'Understanding why farmers plant trees in the homestead agroforestry in Bangladesh', *Agroforestry Systems*, 50(1): 77-93.

Singh, C.D. (2000), 'Valuation and evaluation of trees outside of the forest (TOF) of Bangladesh', draft paper for a regional study for Asia and Pacific in contribution to the Forest Resource Assessment (FRA), FAO, Rome.

Soemarwoto, O. (1987), 'Homegardens: a traditional agroforestry system with promising future', in H.A. Steppler and P.K.R.Nair (eds), *A Decade of Development, ICRAF*, Nairobi, pp. 157-170.

Appendix A

Tree and Bamboo Species with their Usage and Average Number of Stems (*girth ≥ 10 cm) According to Landholding Sizes

SL	English name	Scientific name	Usage	Ma	S	Me	L	OA	%
				Average number of stems					
1F	Jackfruit	*Artocarpus heterophyllus* Lamk.	F, HT, Fu, Fo, M	7.2	10.1	17.5	32.2	11.5	12.3
2F	Mango	*Mangifera indica* Linn.	F, LT, Fu, Fo, M	4.0	5.9	10.1	14.2	6.3	6.8
3T	Mahogany	*Swietenia macrophylla* King	HT, Fu	3.2	4.8	9.5	8.3	5.2	5.5
4F	Coconut	*Cocos nucifera* Linn.	F, LT, Fu, M, C	1.7	2.5	5.7	9.2	3.1	3.3
5F	Guava	*Psidium guajava* Linn.	F, Fu, M	2.0	2.3	4.5	7.2	2.9	3.1
6T	Silk tree	*Albizia procera* (Roxb.) Benth.	HT, Fu	1.4	2.5	4.1	8.7	2.7	2.9
7F	Jujube	*Ziziphus mauritiana* Lamk	F, LT, Fu, Fo, M	1.6	2.4	3.9	5.0	2.5	2.7
8T	Teak	*Tectona grandis* L.f.	HT	1.3	2.2	4.1	4.0	2.2	2.4
9F	Betel nut	*Areca catechu* Linn.	F	0.8	1.7	3.9	6.2	2.0	2.1
10T	Kadam	*Anthocephalus chinensis* (Lamk.) Rich	LT, Fu	1.5	1.3	3.0	4.8	1.9	2.0
11F	Indian blackberry	*Syzygium cumini* (L.) Skeels	F, MT, Fu, M	1.3	1.6	2.3	5.3	1.8	2.0
12T	Acacia	*Acacia auriculiformis* Cunn.	MT	0.9	0.9	5.1	4.5	1.8	2.0
13F	Litchi	*Litchi chinensis* Sonn	F, LT, Fu	0.7	1.3	2.8	6.0	1.5	1.6
14F	Fan palm	*Borassus flabellifer* Linn.	F, LT, C	0.2	1.1	4.1	5.8	1.5	1.6
15T	Rain tree	*Samanea saman* (Jacq.) Merr.	MT, Fu	0.9	1.2	2.3	4.8	1.5	1.6
16F	Date palm	*Phoenix sylvestris* (Linn.) Roxb.	F, J, C	0.6	0.8	1.8	5.5	1.2	1.3
17F	Bael fruit	*Aegle marmelos* (Linn.) Correa	F, LT, Fu, M	0.4	1.1	1.5	3.8	1.1	1.1
18T	Gmelina	*Gmelina arborea Roxb.*	HT, Fu	0.5	0.5	3.2	2.2	1.1	1.1
19F	Sajna	*Moringa oleifera* Lamk.	F, Fu, Fo	0.6	0.6	2.3	3.3	1.1	1.1
20F	Tamarind	*Tamarindus indica Linn.*	F, LT	0.5	1.1	1.7	2.2	1.0	1.1
21F	Indian olive	*Elaeocarpus robustus* Roxb.	F, LT, M	0.6	0.5	1.6	2.3	0.8	0.9
22T	Sissoo	*Dalbergia sissoo* Roxb. Ex. DC.	MT, Fu	0.2	0.4	2.3	2.7	0.8	0.9
23T	Bajna	*Zanthoxylum rhetsa* (Roxb.) DC.	LT, Fu, VO	0.2	0.5	1.7	3.0	0.7	0.8
24F	Pomelo	*Citrus grandis* (Linn.) Osbeck.	F, LT	0.4	0.6	1.1	1.5	0.7	0.7

Appendix A (Cont.)

SL	English name	Scientific name	Usage	Ma	S	ME	L	OA	%
				Average number of stems					
25[T]	Pitraj	*Aphanamixis polystachya* (Wall) Par.	LT, Fu	0.3	0.6	0.9	2.8	0.7	0.7
26[T]	Arjun	*Terminalia arjuna* W & A	MT, Fu, M	0.6	0.4	0.7	2.0	0.6	0.7
27[T]	Neem	*Azadirachta indica* A.Juss.	LT, Fu, M	0.3	0.4	1.1	2.5	0.6	0.7
28[T]	Minjiri	*Cassia siamea* Lamk.	MT, Fu, Fo	0.1	0.7	0.9	2.3	0.5	0.6
29[F]	Hog plum	*Spondius pinnata* (L.f.) Kurz	F, LT, Fu	0.2	0.4	0.5	2.3	0.5	0.5
30[T]	Lannea	*Lannea coromandelica* (Houtt.) Merr.	LT, Fu, Fo	0.2	0.5	0.7	1.5	0.5	0.5
31[T]	Silk cotton	*Bombax ceiba* Linn.	LT, Fu, C	0.2	0.3	0.7	1.7	0.4	0.5
32[F]	Custard apple	*Annona reticulata* Linn.	F, Fu, M	0.3	0.2	1.0	0.5	0.4	0.4
33[F]	Carambola	*Averrhoa carambola* Linn.	F, Fu, M	0.2	0.4	0.5	1.3	0.4	0.4
34[F]	Pomegranate	*Punica granatum* Linn.	F, Fu	0.2	0.5	0.3	0.8	0.4	0.4
35[T]	Flame tree	*Delonix regia* (Bojer ex Hook) Rafin.	LT, Fu	0.1	0.2	0.9	2.0	0.4	0.4
36[F]	Myrobalan	*Phyllanthus emblica* Linn.	F, MT, M	0.1	0.3	0.7	1.3	0.3	0.4
37[F]	Elephant apple	*Dillenia indica* Linn.	F, MT, M	0.2	0.3	0.4	1.0	0.3	0.3
38[F]	Ebony tree	*Diospyros peregrina Gaertn.*	F, LT, Fu	0.2	0.2	0.7	0.8	0.3	0.3
39[T]	River red gum	*Eucalyptus camaldulensis* Dehn.	LT, Fu	0.3	0.2	0.5	0.7	0.3	0.3
40[F]	Wood apple	*Feronia limonia* (Linn.) Swingle	F, LT, M	0.1	0.2	0.7	1.2	0.3	0.3
41[T]	Sal	*Shorea robusta Gaertn.*	HT, Fu, C	0.1	0.2	0.9	0.3	0.3	0.3
42[T]	Bead tree	*Melia azedarach* Linn.	LT, Fu, M	0.2	0.2	0.5	0.7	0.3	0.3
43[T]	Queen's flower	*Lagerstroemia speciosa* Linn.	HT, Fu	0.0	0.3	0.5	0.8	0.3	0.3
44[F]	Monkey jack	*Artocarpus lakoocha* Roxb.	F, MT, M	0.1	0.2	0.5	0.8	0.2	0.3
45[T]	Toothbrush tree	*Streblus asper* Lour.	LT, Fu, Fo	0.1	0.2	0.4	1.0	0.2	0.3
46[F]	Carissa	*Carissa carandus* Linn.	F, LT, Fu	0.1	0.2	0.4	0.5	0.2	0.2
47[T]	Coral Tree	*Erythrina variegata* Linn.	LT, Fu, Fo	0.2	0.2	0.3	0.2	0.2	0.2
48[T]	Flame of forest	*Butea monosperma* Taub	LT, Fu, Fo	0.1	0.1	0.2	1.0	0.2	0.2
49[T]	Indian laburnum	*Cassia fistula* Linn.	MT, Fu	0.0	0.0.	0.3	0.7	0.1	0.2
50[T]	Mast tree	*Polyalthia longifolia* Benth & Hook.	LT, Fu	0.0	0.0	0.1	1.2	0.1	0.1

Appendix A (Cont.)

SL	English name	Scientific name	Usage	Ma	S	Me	L	OA	%
				Average number of stems					
51[B]	Giant bamboo	*Bambusa balcooa Roxb.*	HP, Fo, B, Th, C	7.1	7.8	16.3	32.3	10.5	11.3
52[B]	Timber bamboo	*Bambusa nutans* Wall. Ex. Munro	HP, Fo, B, Th, C	0.5	4.0	13.9	9.3	4.5	4.8
53[B]	Feathery bamboo	*Bambusa vulgaris* Schrad. Ex Wends	HP, Fo, B, Th, C	2.2	2.2	10.2	13.3	4.3	4.6
54[B]	Bengal bamboo	*Bambusa tulda* Roxb.	HP, Fo, B, Th, C	1.8	2.8	3.1	10.7	3.0	3.2
55[B]	Ranjul bamboo	*Bambusa cacharensis* R. B. Majumdar	Th, Fo, B, C	0.9	1.3	9.1	2.0	2.5	2.7
56[B]	Muli bamboo	*Melocana bambusoides* Trin.	Th, Fo, B, C	0.0	0.0	2.3	18.3	1.6	1.7
57[B]	Tengra bamboo	*Bambusa jaintiana* R.B. Majumdar	Th, Fo, B, C	0.0	2.0	2.0	2.8	1.2	1.3
	Total			49.7	75.4	72.3	273.5	93.5	100

Key: F = fruit, HT = high value timber, MT = medium value timber, LT = low value timber, Fu = fuelwood, Fo = fodder, M = medicinal use, C = cottage industrial use, Vo = vegetable oil, HP = house post, B = basket making, Th = thatching material, Ma = marginal landholding class, S = small landholding class, Me = medium landholding class, L = large landholding class, OA = overall. Note: Superscripts F, T and B denotes fruit, timber and bamboo species respectively. * Girth for mature trees was measured at 1.3 m height but for saplings and bamboo at 10 cm above ground.